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Phenological and morpho-physiological development, sex expression and production potential of black and stripped rind varieties of watermelon (*Citrullus lanatus*) in Bangladesh

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ABSTRACT

Although large variations in growth and development patterns and yield potentials among the watermelon (*Citrullus lanatus* (Thunb.) Matsum., and Nakai) varieties are exist, no study covering such issues is reported. The study was conducted in the Crop Botany Field Laboratory, Bangladesh Agricultural University, Mymensingh (24°72´N and 90°42´E, 18 masl) during the post winter season of 2018 and 2019 to provide information on phenophase and morpho-physiological development in terms of vegetative and reproductive growth of vine along with yield potentials of four varieties of watermelon such as Sonya, Black Dorin, Badsha and Dragon. Significant variation in number and length of creepers and sub-creepers, number and size of leaves, number of male and female flower and sex expression ratio, yield components and fruit yield, sweetness index and benefit/cost ratio (BCR) of watermelon was found within the varieties studied. Such variations can solely be described due to the variation in genetic makeup of the cultivars as these were grown with similar edaphic and climatic conditions as well as same management practices. The watermelon varieties Dragon and Badsha took 3 months to mature first fruit while the remaining varieties need more 10 days. Vine growth and development, yield components, fruit yield and BCR were found in the order of Dragon>Badsha>Black Dorin>Sonya. Black rind varieties like Badsha and Black Dorin exhibited higher sweetness index as compared to stripped rind varieties i.e. the others. Irrespective of varieties, the values of the aforesaid traits were found higher in 2018 as compared to those found in 2019 which can be explained due to the variation in climatic parameters as initial growing season of 2018 was dry and warmer than 2019 year.

Keywords: Benefit cost ratio, Creeper, Dioeceous, Hermaprhrodite, Monoecious, Sex ratio, Vine growth, Watermelon

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1. INTRODUCTION

Watermelon *Citrullus lanatus* (Thunb.) Matsum., and Nakai) was formerly *Citrullus vulgaris* belongs to the family Cucurbitaceae (Schippers, 2000), is an important vine crop worldwide (Goreta et al., 2005; Guner and Wehner, 2004; Dane 2005; Tóth et al., 2007; Huh et al., 2008), with an annual production of over 111 million tons (FAOSTAT, 2017). Commercial cultivars are classified as *Citrullus lanatus* var. *lanatus*, while the wild accessions are *Citrullus lanatus* var. *citroides*. Watermelon was originated from Kalahari and Sahara deserts of Africa (Thompson and Kelly, 1957; Jarret et al., 1996), the areas which are considered to be the point of diversification of some other crops too (Schippers, 2000).

Watermelon is classified as a tender warm season crop and is native to the Old World Tropics and Subtropics (Bates and Robinson, 1995) and can be grown up to an elevation of 1524 meters above sea level (Murthy, 1963). It has been commercially cultivated for thousands of years as a vegetable crop. It requires relatively less amount of water as compared to other crops thus its cultivation offers high return (Wang et al., 2004). Watermelon is predominantly consumed its edible flesh as a dessert while its seeds are somewhere used as a staple food. In Africa, it is consumed as a processed vegetable. In Russia, watermelon is a staple food eaten pickled and used for production of syrup by boiling the sugary flesh. In China, firm fleshed watermelon cultivars are cut into strips and dried for use as pickles or glace candy (Sing et al., 2001). Nevertheless, watermelon is also utilized as an animal feed. It has high nutritive value, rich in vitamin 'C' which is good for health, low in sugar (6%) and calories because of high percentage of water (92%). It also contains Lycopene - a red colored carotenoid pigment ($C_{40}H_{56}$) that acts as an antioxidant for human health.

Watermelon is a traditional fruit during early summer harvested through March to June in Bangladesh with its capacity to boost nutrition and food security, and uphold socioeconomic development and as it is mostly cultivated in underutilized land. Smallholder farmers in Bangladesh grow watermelon in Barisal, Faridpur, Natore, Chattagram, Chuadanga and Jhinaidah regions especially to their sandy dry river bank areas mostly in dry pre-monsoon season. Watermelon is also cultivated in many low land areas after receding monsoon water in north-east and north-west region of Bangladesh. However, many farmers are cultivating watermelon now-a-days after post monsoon time from October that provides fruit during off-season time in winter. Beside the cultivation of watermelon on soil ground, it is also practiced on bamboo platforms even at the edge of a pond or waterlogged land (Daily Star, 2021). Watermelon is cultivated in near about 15,740 hectares of land in Bangladesh and an annual production of 2,74,000 metric tons with an average fruit yield of 17.14 t/ha (Biswas, 2020). This low yield indicates that there is a plenty of scope to increase the watermelon yield without increasing the land for its cultivation in Bangladesh.

The phenological development of watermelon crop can be described as the successive appearance of the different stages of growth such as seedling emergence stage, vegetative stage, flowering stage, fruit formation and ripening stages. Accordingly, growth of watermelon can be measured as an increase in number and length of creepers (i.e. vines) and sub-creepers with concomitant increase in the number of nodes or leaves, leaf length and width, foliage bulk, biomass weight etc. To support canopy extension with time, the watermelon vines are capable to produce adventitious roots from every node to uptake water and mineral nutrients from the soil. The growing watermelon crop canopy is observed to spread over area horizontally in every stage. Nevertheless, it can also easily creep vertically provided physical support. Yield performance of watermelon differs among the cultivars due to variation in vine length, number of branches or creepers/sub-creepers, number of nodes, length of internodes, number of male and female flowers and their sex ratio, and fruit number and weight. Most watermelon cultivars are monoecious, and the ratio of staminate to pistillate flower can be modified by climatic and environmental factors (Nitsch et al., 1952; Rudich and Peles, 1976; Buttrose and Sedgley, 1978). These characters may differ in their adaptability to environmental conditions as well as their variation in genetic makeup. Although these are highly important for full-fledged understanding of the nature of progress of watermelon development, however, no comprehensive study covering contrast characteristics of its varieties is reported.

There is also a little information regarding the relative performance on yield components and yield potential of watermelon cultivars grown during the different years of interest. Comparative studies on watermelon cultivar's growth and yield performance in years with different climatic conditions are quite important for developing new options for plant breeding. Therefore, the aim of the study was to observe the phenophase and morpho-physiological development and associated vegetative and reproductive growth habit of some watermelon cultivars, and to examine the likely climatic parameters causing the difference in growth and yield potential in each year by comparing the growth performance of the plant.

2. MATERIALS AND METHODS

2.1. Experimental site

The study was conducted in the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University (24°72′N latitude and 90°42′E longitude and 18 m above the sea level), Mymensingh during the spring and pre-summer season extended

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from February to May 2018. The experiment was repeated through the same time period in subsequent year i.e. 2019. Geographically, the experimental field was medium high land belonging to the non-calcareous, dark-grey flood plain soil under the Sonatola series of Old Brahmaputra Flood Plain. It is located at Agro-Ecological Zone 9 (AEZ #9). Major micrometeorological parameters were recorded in daily basis with appropriate devices in a Meteorological Observatory that is located within half of a kilometer from the experimental site.

2.2. Land and pit preparation and fertilization

The land of the experimental area was first opened with a power tiller and it was made ready for sowing by ploughing with a power tiller followed by laddering. The corner of the land was spaded and visible larger clods were hammered to break into small pieces. All weeds and stubbles were removed from the land. The entire experimental land was fertilized with well rotten cow dung @ 10 t/ha. The pit method cultivation technology was followed (Ramesh et al., 2013) and all chemical fertilizers were applied in the pits. The pit soil was fertilized with 125 kg nitrogen, 75 kg phosphorus, 60 kg potassium, 3 kg boron and 3 kg zinc per hectare (Kacha et al., 2017; Cecílio Filho et al., 2015) from the source of urea, triple super phosphate, muriate of potash, boric acid and zinc sulphate, respectively. All fertilizers and one-third amount of nitrogen were properly mixed with pit soil during final pit preparation. The rest of amount of nitrogen fertilizer was applied in equal two splits, the first at 30 day and the second at 45 days after seed sowing.

2.3. Experimental design and layout

The experiment comprised of four varieties of watermelon as treatments viz. Sonya, Black Dorin, Badsha and Dragon which were grown following the Completely Randomized Design (CRD) in plot with three replicates. The plot size was 7m × 4m. Inter-plot distance was 1 m. Each plot was equally divided into four sub-plots. A pit of 60 cm diameter was prepared in the centre of each sub-plot. Pit height was 10 cm for avoiding water-logging conditions due to rain or related reasons.

2.4. Seed sowing and crop management

Ten seeds were sown in each pit manually at 2-3 cm soil depth following the round-shaped pattern with a 15 cm distance from the periphery of the pit. After seedling emergence, thinning operation was performed time to time and finally three healthy plantlets roughly equally spaced to each other were kept in each pit for subsequent growth and development. Various sorts of intercultural operations like crust breaking, soil loosening, application of water, weeding, insect and disease pest management etc., were performed as and when required. Vine creeping was regularly noticed. No manipulation in vine growth like training, pruning, leaf clipping etc. was performed.

2.5. Data collection

Seedling height from stem base to the apex of the seedling was recorded at 10 days after sowing (DAS) and 30 DAS. The mother or cotyledonary vine was tagged before initiation of other vines. Phenophase development like days to appearance of first leaf, first branch, first male flower and first female flower, and days to first physiological maturity of fruit were recorded. The number of newly bloomed male and female flowers was separately counted every morning as the petals gradually desiccate with progress of the day. The male flower and female flower are open in the separate nodes of watermelon vine. Male flower opens first and after few days female flower from the same plant opens. Flowering count was commenced from the first flowering until the end of flowering. Sex ratio was determined as the total number of male flower divided by the total number of female flower which opened from a plant.

Leaf length, leaf breadth, leaf area and leaf dry matter was recorded from the upper most fully expanded leaves. Vine diameter from the internode followed by top most completely developed leaf was measured with a Slide Caliper. Leaf area was measured with an Electronic Area Meter (LI 3000, USA) and then their corresponding dry weight was recorded after drying at 80±2^{o}C with a fan-forced oven until constant weight. The SLA was calculated by the ratio between the leaf area and the leaf dry matter.

Number of primary vines (the vines those were originated from the mother vine), total number of vines, vine length and node number in vines were recorded during final harvest. Each node in a vine of watermelon plant births a leaf, thus number of nodes represents the number of leaves. Otherwise, the number of node in a vine was calculated as:

$$\text{No. of nodes} = \text{No. of internodes} + 1$$

Internode length in a vine was calculated as the length of vine divided by the number of node in the respective vine. That is,

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$$\text{Internode length} = \frac{\text{Length of vine}}{\text{No. of node in vine}}$$

Physiological maturity of watermelon fruit indicates the drying of the tendril closest to the fruit (Cecílio Filho et al., 2015). Immaturely formed fruits, tiny fruits and fruits without edible flesh were discarded i.e. not taken into account for yield analysis. Market price of watermelon fruit near the local fruit market (Mymensingh town market) were recorded especially for the type and size of the watermelons those were harvested from experimental plots. Sweetness index or Brix or total soluble solids (TSS) content of watermelon fruit was measured by a hand-held Refractometer (Atago Co., Brix-Meter, Tokyo, Japan).

Harvested fruits were weighed to economic value accordingly. A well-structured budget analysis along with input cost (non-materials and materials) and overhead cost was used to calculate the production cost. Thereafter, gross and net economic margins were calculated. Benefit-cost ratio (BCR) was computed as net economic profit over total cost of production.

2.6. Statistical analysis

All data were compiled and analyzed with a Statistical Package Programme developed by Russel (1986). The collected data on different parameters were analyzed statistically to obtain the level of significance using the MSTAT-C. Least Significant Difference (LSD) was computed for easy comparing between the pair of means. The difference between the average values of the treatments was compared by Duncan's Multiple Range Test, DMRT (Gomez and Gomez, 1984).

3. RESULTS

3.1. Micrometeorological condition nearby study area during experimental period

The major micrometeorological parameters during the study period are shown in Table 1. Difference between mean maximum (around 30 ^{o}C) and mean minimum temperature during February and March months was >10^{o}C but the variation was squeezed to less than 10^{o}C during the subsequent months. Although the reading of such temperatures were found higher in 2019 than the 2018 year in all months of experimentation except February and March where both maximum and minimum temperature were higher in 2018. The lower temperature in February and March months in 2019 can be elucidated by the larger amount of rainfall. Wind speed remained lower in January and February months and thereafter increased gradually with progress of the season.

3.2. Seedling elongation

The young plantlets of watermelon developed with 3-7 cm height at 10 DAS to 19-34 cm at 30 DAS (Table 2). The variation in seedling height within the watermelon varieties was found significant for both growing years. The crop grown with the variety Sonya produced shorter seedling and Badsha or Dragon produced the taller seedling both at 10 DAS and 30 DAS while the seedling raised from the variety Black Dorin exhibited intermediate in stature. Irrespective of the varieties and growing years, seedlings raised during 2019 year shown shorter height as compared to those raised during the 2018 year.

Table 1: Major micrometeorological parameters during the study period in 2018 and 2019 years

Micrometeorological Parameter	Year	Month			
		February	March	April	May
Max. Temp (^{o}C)	2018	29.1±1.8	31.1±1.6	30.4±2.3	30.2±2.9
	2019	27.0±1.8	29.8±2.5	31.7±2.7	32.6±2.4
Min. Temp (^{o}C)	2018	16.0±2.1	20.0±1.8	21.4±1.5	23.5±2.4
	2019	15.5±2.0	18.9±2.6	22.3±2.3	24.2±1.8
Total Rainfall (mm)	2018	0.0±0.0	33.1±3.1	915.3±130.4	488.5±35.0
	2019	29.8±4.7	51.7±6.7	67.0±6.2	332.0±20.6
Mean RH (%)	2018	76.8±7.6	76.1±5.2	79.1±7.8	83.2±5.7
	2019	75.9±6.2	73.0±6.1	78.5±5.1	80.4±5.0
Sun Duration (hr/day)	2018	6.1±2.4	6.2±2.5	6.1±3.3	4.8±3.3
	2019	5.9±3.1	6.7±2.7	6.5±3.0	6.1±3.2
Wind Speed (kmph)	2018	3.1±1.6	4.8±2.4	6.7±2.3	7.9±2.1
	2019	3.4±2.1	4.3±2.3	5.8±2.4	9.0±2.4

Value followed by '±' sign represents the daily variation

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Table 2: Seedling elongation (cm) of four varieties of watermelon at 10 and 30 DAS

Year	Cultivar	Seedling elongation (cm)	
		10 DAS	30 DAS
Year × Cultivar			
2018	Sonya	3.73 c	19.46 bc
	Black Dorin	5.06 b	22.03 b
	Badsha	5.70 ab	34.13 a
	Dragon	6.50 a	30.96 a
2019	Sonya	3.26 c	12.96 d
	Black Dorin	3.43 c	15.56 cd
	Badsha	5.10 b	20.03 bc
	Dragon	3.70 c	15.50 cd
	LSD 0.01	0.80	5.54
Cultivar	Sonya	3.50 c	16.21 c
	Black Dorin	4.25 b	18.80 bc
	Badsha	5.40 a	27.08 a
	Dragon	5.10 a	23.23 ab
	$LSD_{0.01}$	0.71	5.38
Year	2018	5.25 a	26.65 a
	2019	3.57 b	16.01 b
	$LSD_{0.01}$	0.71*	6.24

Values with similar letter in a column do not differ significantly at 1% level of probability (except *P<0.05)

Table 3: Phenological development of four varieties of watermelon grown during 2018 and 2019 years

Year	Cultivar	Days to first leaf appearance	Days to first branch appearance	Days to first male flower appearance	Days to first female flower appearance	Days to fruit maturity
Year × Cultivar						
2018	Sonya	12.3 ab	22.0 b	51.7 ab	57.3 abc	102.7 a
	Black Dorin	11.333 ab	24.0 ab	50.7 abc	55.7 abc	101.7 a
	Badsha	10.0 b	23.0 ab	47.0 c	50.7 c	91.0 b
	Dragon	10.7 ab	22.3 ab	47.3 bc	51.7 bc	90.7 b
2019	Sonya	12.7 a	25.3 ab	52.0 a	59.0 a	105.3 a
	Black Dorin	11.7 ab	26.7 a	51.7 ab	57.7 ab	103.3 a
	Badsha	10.3 ab	24.7 ab	47.7 abc	52.7 abc	92.7 b
	Dragon	11.0 ab	24.7 ab	47.7 abc	52.7 abc	92.3 b
	$LSD_{0.01}$	2.4	4.4	4.5	6.9	5.0
Cultivar	Sonya	12.5 a	23.7 a	51.8 a	58.2 a	104.0 a
	Black Dorin	11.5 ab	25.3 a	51.2 ab	56.7 a	102.5 ab
	Badsha	10.2 b	23.8 a	47.3 b	51.7 b	91.8 b
	Dragon	10.8 ab	23.5 ab	47.5 b	52.2 b	91.5 b
	$LSD_{0.01}$	1.9	1.8	3.9	4.4	4.4
Year	2018	11.1	22.8 b	49.2 b	53.8 b	96.5 b
	2019	11.4	25.3 a	49.8 a	55.5 a	98.4 a
	$LSD_{0.01}$	NS*	2.5	0.5	1.6	1.8

Values with similar letter in a column do not differ significantly at 1% level of probability (except *P<0.05). NS = Non significant

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3.3. Phenophase development

Watermelon plant needs about 10 to 13 days from seed sowing to appear the first leaf (Table 3). The variety Badsha took the shortest time while Sonya took the longest time to appear the first leaf in the mother vine. But the year effect on the time variation for the appearance of first leaf in the mother vine of watermelon was found statistically insignificant.

Days to first branch (i.e. first primary branch) appearance in the watermelon plants was reported about 22 to 27 days from seed sowing (Table 3). As like to the appearance of first leaf, the time variation for the appearance of first branch among the watermelon varieties was found statistically significant. The variety Black Dorin took the longest time to appear first mother vine while dragon took the shortest time. The time variation for the appearance of first primary vine in the watermelon varieties in the two successive years was also found statistically significant. First branch was recorded to appear earlier in 2018 year than that at 2019.

Watermelon plant needs about 7 weeks to appear the first male flower (Table 3). The variety Sonya or Black Dorin took the longest time to appear the first male flower while Badsha or Dragon took the relatively shorter number of days for the same purpose. The first female flower appeared about 5-7 days following the appearance of first male flower (Table 3). The time variation to bloom the plants with female flower for the different watermelon varieties and year of cultivation was found statistically significant. The variety Sonya took the larger number of days whereas the variety Badsha or Dragon took the lower number of days for offering the first female flower in the plants.

The time variation to harvest mature fruits from the different varieties in two different years was found statistically significant. The watermelon variety Sonya took the largest number of days about 100 plus a few days to mature the fruit whereas the varieties Badsha and Dragon took about 3 months for the same purpose (Table 3). The 2019 year expended additional two days than 2018 to mature the fruits.

3.4. Creeper (vine) growth

The watermelon stem creeps with movement of the vine. The variation in mother vine (main creeper) length produced by the different varieties of watermelon was found significant (Table 4). The variety Dragon produced the longest vine followed by the variety Badsha. In contrast, the Sonya produced the shortest vine while the vine produced by the variety Black Dorin ranked in middle length. Irrespective of the varieties, the watermelon's vine produced in the 2018 year was longer in size as compared to that produced in the 2019 year. The variation in length of primary vine produced by the different watermelon varieties in two successive years followed the length of mother vine but with about 30 percent less extension (Table 4).

The mother vine produced about 4 to 7 primary vines (primary creepers) during the entire growth period of watermelon plants. The variety Dragon or Black Dorin produced the higher number of primary creepers followed by the variety Badsha while the Sonya produced the lesser number of primary vines (Table 4). Irrespective of the varieties, the number of primary vine produced in 2019 was lesser in number as compared to that produced in 2018.

With the contribution of secondary vines (the vines those produced from the primary vines) along with successive order of vines, the watermelon plant produced total 8 to more than 12 vines (cotyledonary or mother creeper + primary creepers + secondary creepers and so on). The variety Dragon or Badsha produced the larger number of vine followed by the variety Black Dorin while the Sonya produced the lesser number of vines (Table 4). As like as the number of primary vines, the number of total vine produced in 2019 was lesser in number as compared to that produced in 2018 year.

The watermelon variety Dragon produced thicker vine (both the mother vine and primary vine) followed by the variety Badsha and Black Dorin but with same statistical rank while the Sonya produced comparatively thinner ones (Table 4). Irrespective of the varieties and year of cultivation, mother vines were found thicker than those of primary vines. Watermelon plants grown in 2018 year produced thicker vines as compared to the vines produced from the plants in 2019 year.

The watermelon plants crept with about 35 to 50 nodes in mother vine. The watermelon variety Dragon crept with producing higher number of nodes in the mother vine followed by the variety Badsha or Sonya while Black Dorin produced the lesser number of nodes (Table 4). Irrespective of the varieties, the watermelon plants crept with lesser number of nodes in mother vine in 2019 as compared to that in 2018.

The mother vine of watermelon plants was reported to creep with 5 to 7 cm inter-node length. The variety Badsha or Black Dorin crept with longer internode followed by the variety Drgaon while the variety Sonya crept with shorter internode (Table 4). The effect of the year of cultivation for inter-node length was found insignificant.

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Table 4: Vine growth of four varieties of watermelon grown during 2018 and 2019 years

Year	Cultivar	No. of vine		Vine length (cm)		Vine diameter (mm)		No. of node in primary vine	Internode length in primary vine (cm)
		Primary	Total	Mother	Primary	Mother	Primary		
Year × Cultivar									
2018	Sonya	4.66 cd	9.33 ab	232.3 cd	149.7 d	0.416 bc	0.316 b	44.3 abc	5.25 b
	Black Dorin	6.66 ab	10.00 ab	255.0 bc	181.3 c	0.486 ab	0.396 a	39.0 bc	6.56 a
	Badsha	6.00 abc	11.66 a	299.0 a	216.7 a	0.500 a	0.406 a	46.0 ab	6.53 a
	Dragon	7.00 a	12.33 a	281.0 ab	211.3 ab	0.526 a	0.426 a	49.3 a	5.71 ab
2019	Sonya	4.33 d	8.00 b	194.3 e	136.7 d	0.366 c	0.303 b	38.7 bc	5.02 b
	Black Dorin	5.66 abcd	9.00 ab	233.3 cd	152.0 d	0.420 bc	0.380 a	35.7 c	6.55 a
	Badsha	5.33 bcd	10.33 ab	216.7 de	189.3 bc	0.460 ab	0.390 a	43.7 abc	6.43 a
	Dragon	6.33 ab	11.33 ab	248.3 bcd	188.0 bc	0.473 ab	0.400 a	42.0 abc	5.95 ab
	$LSD_{0.01}$	1.62	3.47	33.3	24.6	0.070	0.050	9.46	0.94
Cultivar	Sonya	4.50 b	8.66 b	213.3 c	143.2 c	0.391 b	0.310 b	41.5 ab	5.14 b
	Black Dorin	6.16 a	9.50 ab	244.2 b	166.7 b	0.453 a	0.388 a	37.3 b	6.55 a
	Badsha	5.66 ab	11.00 a	260.3 ab	203.0 a	0.480 a	0.398 a	44.8 ab	6.48 a
	Dragon	6.66 a	11.83 a	264.7 a	199.7 a	0.500 a	0.413 a	46.7 a	5.83 ab
	$LSD_{0.01}$	1.57	2.32	18.0	19.5	0.050	0.038	8.12	0.76
Year	2018	6.03 a	10.83 a	266.8 a	189.8 a	0.480 a	0.380 a	44.7 a	6.01
	2019	5.41 b	9.66 b	223.2 b	166.5 b	0.430 b	0.360 b	40.0 b	5.98
	$LSD_{0.01}$	0.60	1.10	38.8	23.2	0.050	0.110	4.62	NS*

Values with similar letter in a column do not differ significantly at 1% level of probability (except *P<0.05). NS=Not significant

Table 5: Leaf growth of four varieties of watermelon grown during 2018 and 2019 years

Year	Cultivar	Leaf length (cm)		Leaf breadth (cm)		SLA (cm^2/g)	
		Mother vine	Primary vine	Mother vine	Primary vine	Mother vine	Primary vine
Year × Cultivar							
2018	Sonya	13.6 ef	10.5 c	11.1 bc	8.7 de	169.9	176.1
	Black Dorin	17.2 abc	13.5 a	11.2 bc	10.1 bc	178.6	186.0
	Badsha	18.2 ab	13.6 a	12.5 ab	10.1 bc	179.6	184.6
	Dragon	18.8 a	14.6 a	13.6 a	11.7 a	183.9	192.1
2019	Sonya	12.4 f	10.2 c	9.3 d	7.9 e	164.7	174.5
	Black Dorin	14.7 de	12.9 ab	9.4 d	9.4 cd	175.0	190.1
	Badsha	15.1 cde	11.4 bc	10.4 cd	9.3 cd	169.8	180.0
	Dragon	16.4 bcd	11.2 bc	11.7 bc	10.9 ab	189.0	197.8
	$LSD_{0.01}$	2.1	1.7	1.4	1.06	NS*	NS*
Cultivar	Sonya	13.0 b	10.3 c	10.2 b	8.3 c	167.3	175.3
	Black Dorin	15.9 a	13.2 a	10.3 b	9.7 b	176.8	188.1
	Badsha	16.6 a	12.5 b	11.5 ab	9.7 b	174.7	182.3
	Dragon	17.6 a	12.9 ab	12.6 a	11.3 a	186.5	194.9

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	$LSD_{0.01}$	1.8	0.5	1.3	0.6	NS*	NS*
Year	2018	16.9 a	13.0	12.1 a	10.2 a	178.0	184.7
	2019	14.6 b	11.4	10.9 b	9.4 b	174.6	185.6
	$LSD_{0.01}$	1.3	NS*	1.9	0.7	NS*	NS*

Values with similar letter in a column do not differ significantly at 1% level of probability (except *P<0.05). NS=Not significant

Table 6: Sex expression of four varieties of watermelon grown during 2018 and 2019 years

Year	Cultivar	No. of male flower/plant	No. of female flower/plant	Male/female flower ratio
Year × Cultivar				
2018	Sonya	64.3 c	6.3 ab	10.3 ab
	Black Dorin	73.3 bc	6.8 ab	11.1 ab
	Badsha	90.0 a	9.0 a	10.0 ab
	Dragon	91.3 a	7.4 ab	12.4 a
2019	Sonya	61.0 cd	6.6 ab	9.3 ab
	Black Dorin	48.6 d	5.9 b	8.4 b
	Badsha	80.3 ab	8.1 ab	10.0 ab
	Dragon	80.3 ab	7.3 ab	11.1 ab
	$LSD_{0.01}$	13.62	0.04	1.35
Cultivar	Sonya	56.5 b	6.1 b	9.3 b
	Black Dorin	67.1 b	6.7 b	10.2 a
	Badsha	85.1 a	8.5 a	10.0 a
	Dragon	85.8 a	7.3 ab	11.7 a
	$LSD_{0.01}$	14.5	1.5	2.3
Year	2018	79.7 a	7.4	10.9 a
	2019	67.5 b	7.0	9.6 b
	$LSD_{0.01}$	12.1	NS*	1.2

Values with similar letter in a column do not differ significantly at 1% level of probability (except *P<0.05). NS = Not significant

3.5. Leaf growth

Both the leaf length and leaf breadth are considered as the measure of leaf size. The watermelon variety Dragon grown with larger size of leaves (in length) produced in mother vine followed by the Badsha or Black Dorin but with same DMRT group while the variety Sonya grown with smaller leaf length (Table 5). Irrespective of varieties, the length of leaves in mother vines was found smaller in size in 2019 than that at 2018. The varietal difference in the length of leaves produced in primary vines was somewhat similar to that produced in mother vines but the year effect was found insignificant.

The watermelon variety Dragon grown with wider sizes of leaves (as breadth) produced both in mother and primary vines followed by the variety Badsha or Black Dorin while the variety Sonya grown with narrower ones (Table 5). The leaf breadth was found narrower in 2019 than that at 2018. The leaf size (in consideration of leaf length and breadth) was found wider that produced on mother vine as compared to the leaves those produced on the primary ones and else.

The specific leaf area (SLA) is defined as leaf area per unit of dry matter of leaf which is a gauge of leaf thickness (or thinness) as well as leaf spread capacity. The SLAs across the varieties were found in the order of Dragon>Black Dorin>Badsha>Sonya (Table 5). However, the difference among the varieties was insignificant. The SLA values of leaves found from mother vine (165-189 cm^2/g) were found higher than those observed in primary vines (175-198 cm^2/g) but their variation is not statistically significant. The difference of SLAs among the years was also not distinct (i.e. insignificant).

3.6. Sex expression of watermelon cultivars

The watermelon variety Dragon or Badsha bloomed with greater number of male flowers and Black Dorin with lesser number throughout their growing period. While the number of male flowers opened from the variety Sonya ranked intermediate (Table 6). However, the difference between Black Dorin and Sonya for the production of male flower was not statistically significant. The

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watermelon plant irrespective of the varieties bloomed with higher number of male flowers in 2018 as compared to that boomed in 2019 year.

The watermelon variety Badsha opened the greater number of female flowers followed by the variety Dragon while the variety Sonya or Black Dorin opened the lesser number of female flowers throughout their reproductive age (Table 6). However, the year effect in this regard was not significant.

The sex ratio (i.e. male/female flower ratio) of watermelon varieties was found more than 9 (Table 6). The variety Dragon credited with higher sex ratio followed by the Sonya or Badsha but with same statistical rank while Black Dorin credited with lower sex ratio. The watermelon varieties grown in 2018 year favoured with higher male/female flower ratio than that at 2019.

3.7. Yield components and yield

On maturity, about two healthy fruits were persisted in each watermelon plant. The variety Badsha or Dragon persisted with higher number of fruit per plant while the remaining two varieties yielded the lower ones (Table 7). The watermelon plants grown in 2018 experimental year offered more than two fruits per plant while it was less than two in 2019. The quantitative nature of the other yield components like weight of individual fruit and fruit weight per plant shown the similar trend for the varieties and experimental years as those described for the number of fruit per plant (Table 7). For example, the watermelon variety Dragon produced the larger fruit (>3 kg/fruit) followed by the variety Badsha while the Sonya or Black Dorin produced the individual fruit with smaller size, and similar trend was found for fruit weight per plant.

Among the watermelon varieties, the Dragon produced the larger fruit yield and Back Dorin or Sonya produced the smaller ones (Table 7). While the variety Badsha yielded the fresh fruit that ranked in between. Irrespective of the watermelon varieties, the fresh fruit yield was found significantly higher in 2018 as compared to that yielded in 2019 year (Table 7).

Irrespective of the watermelon varieties, the brix (fruit quality) or sweetness index was found more than 10-unit. The brix was found higher in the Badsha and Black Dorin varieties (i.e. the black rind varieties) and lower brix was recorded in the Sonya while Dragon's brix was ranked as intermediate position (Table 7). The year effect for this trait was nil.

Table 7: Yield analysis of four varieties of watermelon grown during 2018 and 2019 years

Year	Cultivar	No. of fruit/ plant	Weight (kg)/ fruit	Fruit weight (kg/plant)	Fruit yield (t/ha)	Sweetness index or Brix$^{\xi}$
Year × Cultivar						
2018	Sonya	1.99 a	2.45 de	4.90 cd	21.03 cd	9.86 e
	Black Dorin	1.93 a	2.67 cd	5.17 bcd	22.20 bcd	11.86 c
	Badsha	2.12 a	2.95 bc	6.23 ab	26.75 ab	12.56 b
	Dragon	2.03 a	3.41 a	6.95 a	29.83 a	10.70 d
2019	Sonya	1.83 b	2.23 e	4.07 d	17.48 d	10.13 e
	Black Dorin	1.86 a	2.41 de	4.51 d	19.37 d	12.00 bc
	Badsha	1.76 ab	2.83 c	5.24 bcd	22.52 bcd	12.66 a
	Dragon	1.82 b	3.28 ab	5.98 abc	25.69 abc	10.43 de
	$LSD_{0.01}$	0.27	0.33	1.26	5.40	0.61
Cultivar	Sonya	1.91 ab	2.34 c	4.48 c	19.26 c	10.00 d
	Black Dorin	1.90 ab	2.54 c	4.84 bc	20.79 bc	11.93 b
	Badsha	1.98 a	2.89 b	5.74 ab	24.64 ab	12.61 a
	Dragon	1.92 a	3.35 a	6.46 a	27.76a	10.56 c
	$LSD_{0.01}$	0.03	0.26	1.12	4.80	0.40
Year	2018	2.02 a	2.84 a	5.81 a	24.96 a	11.25
	2019	1.84 b	2.68 b	4.95 b	21.27 b	11.30
	$LSD_{0.01}$	0.05	0.16	0.81	3.62	NS*

$^{\xi}$Brix is the percentage of sucrose, fructose in 100 pounds of juice.

Values with similar letter in a column do not differ significantly at 1% level of probability (except $^{*}P<0.05$). NS = Not significant

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Table 8: Economic analysis for cultivation of four varieties of watermelon varieties grown during 2018 and 2019 years

Year	Cultivar	Gross income (BDT/ha)	Net profit (BDT/ha)	Benefit/Cost ratio (BCR)
Year × Cultivar				
2018	Sonya	1051921 cd	684451 cd	1.862 cd
	Black Dorin	1110313 bcd	742842 bcd	2.021 bcd
	Badsha	1337829 ab	970359 ab	2.640 ab
	Dragon	1491840 a	1124370 a	3.059 a
2019	Sonya	874454 d	506984 d	1.379 d
	Black Dorin	968834 d	601364 d	1.636 d
	Badsha	1126295 bcd	758825 bcd	2.065 bcd
	Dragon	1284765 abc	917294 abc	2.496 abc
	$LSD_{0.01}$	270000	270000	0.73
Cultivar	Sonya	963188 c	595718 c	1.6211 c
	Black Dorin	1039573 bc	672103 bc	1.8290 bc
	Badsha	1232062 ab	864592 ab	2.3528 ab
	Dragon	1388303 a	1020832 a	2.7780 a
	$LSD_{0.01}$	240000	240000	0.65
Year	2018	1247976 a	880506 a	2.396 a
	2019	1063587 b	696117 b	1.894 b
	$LSD_{0.01}$	803000	120000	0.45

Values with similar letter in a column do not differ significantly at 1% level of probability.
BDT = Bangladesh Taka

3.8. Economics for production of watermelon cultivars

Both gross income and net profit for cultivation of the watermelon varieties were found significant (Table 8). The quantitative figure of these traits was ordered as Dragon>Badsha>Black Dorin>Sonya. The economic benefits for water cultivation were higher in 2018 than that at 2019 year. The watermelon variety Dragon credited with greater benefit/cost ratio (BCR). The varietal order of BCR was found as Dragon>Badsha>Black Dorin>Sonya (Table 8). The 2018 growing season shown more than two BCR while the 2019 shown less than two.

4. DISCUSSION

Vine or creeper is the sole organ that governs the advancement of growth of watermelon plant. The plant extends it foliage with production of sub-creepers i.e. through secondary or tertiary or other higher order of vines. That is the vine branches to primary and secondary order, and so on, thus enlarges canopy areas. The structure and function of main creeper and sub-creepers are almost similar in nature. The vines creep with leaving nodes and internodes in regular intervals. The nodes act as the producer of leaves, flowers and fruits. The vine survives only one growing season (i.e. annual habit), grows with indeterminate in nature and if kept undisturbed, can reach up to a length of five meter or even more (Neppl and Wehner, 2001). Large differences in number of vine per plant, length of vine and node number in each vine are also reported else (Yetisir and Uygur, 2009; Karuppaiah, 2010; Adeyeye et al., 2016; Choudhary et al., 2012; Chaudhary et al., 2016a; Yuge et al., 2016; Dadheech et al., 2018; Mrema and Maerere, 2018) which are attributed due to the variation of genetic makeup and environment or growing conditions, and the information in literatures support the results that presented in this study. The scanty information on the internode length, vine diameter, leaf length and breadth that available in Yuge et al. (2016), Oraegbunam et al. (2016), Dadheech et al. (2018), Meshram et al. (2020) and Gulut et al. (2021) are mostly matched that reported in the present investigation. The information on SLA of watermelon is hardly available, however, the SLA figures that found in this study is higher than that reported in the literature (Campagnol et al., 2012).

The day's number to appear the first male and first female flowers of watermelon plants in this study seems little bit longer as Maluki et al. (2016) found 30-32 days and Oraegbunam et al. (2016) found 36-37 days for first male flowering, and Meshram et al. (2020) found only 34-37 days for first female flowering. Karuppaiah (2010) found wide variation in the day's number to both male (37-55 days) and female flowering (38-57 days) in watermelon plants based on the treatment conditions. Nevertheless, Chaudhary

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et al. (2016a) found about 54 days to appear first female flower in watermelon plant that is full conformity with present result. The days required (around 40 days) for reaching fruit maturity after blooming in this study is also confirmed by Nonnecke (1989), however, much shortened days (30-33 days) are also reported (Chaudhary et al., 2016a). Choudhary et al. (2012) found 50-61 days for the appearance of first pistillate flower and 75-100 days for first fruit maturity from a wider number of watermelon genotypes in India that also support our result.

Production related traits of watermelon plant (*Citrullus* spp.) like pollination performance, fruit setting etc. are largely dependent on the sex expressions. Watermelon plants exhibited various types of flowering pattern like monoecious where male and female flowers bloom in the same plant, andromonoecious where male and hermaphrodite or bisexual flowers bloom in the same plant, and trimonoecious where male, female and hermaphrodite flowers bloom in the same plant (Rudich and Zamski, 1985; Ji et al., 2015). Nevertheless, the watermelon plants in this study produced only two types of flowers i.e. male flower and female flowers. Watermelon varieties produced fewer female flowers than the crop plants belong to the cucurbit group (Sugiyama, 1998). When flowering commence in the growing watermelon plant, male flowers reported to produce at every node while female flowers are bloomed approximately every fourth to seventh node, depending on the genotypes or environmental conditions (McGregor et al., 2013; Dadheech et al., 2018). However, Maluki et al. (2016) found thinner sex ratio (5.85-9.24) in watermelon. Karuppaiah (2010), Chaudhary et al. (2016a) and Meshram et al. (2020) found fewer female flowers with a male/female ratio of 8-11, and the information very close to the result found in this study.

The varying number of flowers that produced by the watermelon plants has been ascribed due to the variation in vim and vigour, genetic makeup and conditions of growing environment (Loy, 2004; Dittmar, 2006). Long vines with many nodes and branches have more flowers than those with fewer nodes and branches. The reason for the larger number of male flowers during 2018 year (dry season) than 2019 (wet season) during the early stage of crop development in this study may be explained due to warmer temperature during flower initiation in 2018 year, which favours male flower development (Wein, 1997; Peñaranda et al., 2007).

The number and weight of watermelon fruit depend on vine growth and development and these are influenced by genetic variation and environmental conditions (Dittmar, 2006; Anburani et al., 2019). From an experiment conducted in Pahartali of Chttagram in south-eastern Bangladesh, Salam et al. (2002) found 3.33 fruit per watermelon plant with about 16 t/ha fruit yield. Bernard et al. (2009) found one to five fruits per watermelon plant with each fruit weight of 2-3 kg while Chaudhary et al. (2016a) found 1.87-4.33 fruits per plant with 2.97-7.46 kg individual fruit weight. Not surprisingly, fruit weights with larger variation like 4-18 kg have also been reported by McFarlane (2007) and Mrema and Maerere (2018). Chaudhary et al. (2016a) found 2.02 mature fruit per watermelon plant with an individual fruit weight 3.48 kg in India. The observed fruit yield in this study is supported by Salman et al. (2005), Akintoye et al. (2009), Dadheech et al. (2018) although higher fruit yield as compared to that observed in the present study are also found in the literature (Meshram et al., 2020; Rolbiecki et al., 2020; Gulut, 2021).

Less rain with alternate cool and dry periods during flowering period (i.e. in early crop growth stage) may be the reason for enhanced fruit yields as found in 2018 as movement of honeybees (pollinator) in watermelon field is very important for obtaining a good yield (Taha and Bayoumi, 2009). Rainless condition attracts honeybee to visit in the field. Additionally, regular rain during fruit bulking stage has resulted bigger fruit (weight basis) in 2018 as that found in 2019. That is less rain during early crop development stage (reproductive initiation and fruit set stage) but regular rain during later stage (fruit bulking stage) favour watermelon production. The lighter (smaller-sized) individual fruits which found in this study in both years are almost similar to that recently reported by Dadheech et al. (2018), Meshram et al. (2020) and Rolbiecki et al. (2020), however, production of heavy fruits by watermelon plants are also common in literature (Salman et al., 2005; McFarlane, 2007; Bernard et al., 2009; Gulut, 2021).

Pardo et al. (1997) and Campagnol et al. (2012) found much closer sweetness index or brix 9.1-11.4 from wide varieties of watermelon in India or varied growing conditions in Brazil. Choudhary et al. (2012) found wider range of brix 7.8-17.2 from a larger number of watermelon genotypes in India. Salam et al. (2002) in Bangladesh, and Karuppaiah (2010) and Chaudhary et al. (2016a) in India also found brix around 10 in watermelon varieties which are very close to the result found in this study. The higher sweetness index of watermelon fruits that found in the black rind varieties as compared to the stripped rind ones can be explained due to the darker chlorophyll contents in the former that warrants further investigation.

A benefit cost ratio (BCR) >1.0, =1.0 or <1.0 refer gain, breakeven or loss, respectively. Since, the BCR was found far greater than unity (2.38-3.86) which shows that the cultivation of watermelon varieties used in this study is highly profitable. This affirmed the findings of Namdari (2011), Yusuf et al. (2013), Ajewole (2015), Chaudhary et al. (2016b), Lakdan and Stanzen (2017), Adedapo and Kehinde-Fadare (2020) where BCR in watermelon cultivation was also found greater than unity (1.57-3.65). The higher BCR that found in this study as compared to cited else can be explained due to the involvement of no or less cost for irrigation due to rainfall during the study period. Since, watermelon cultivation was found profitable and it has also been substantiated by the continuous

watermelon cultivation by the farmers, there should be availability of connecting roads to production sites, timely insuring adequate farm inputs, and proper extension service delivery, availability of cultivation land, credit privilege, storage facilities, easy marketing channel and agro-industrial processing to expand the cultivation of watermelon in Bangladesh.

5. CONCLUSION

All phenophase development events occurred earlier in the watermelon varieties Dragon and Badsha which lead to result fruit maturity on a 3-month period while the remaining two varieties Sonya and Black Dorin took additional 10 days. Plant advancement in terms of number and length of creepers and sub-creepers, number and size of leaves, number of male and female flowers and sex ratio, yield components and fruit yield, sweetness index and benefit/cost ratio of watermelon plants was found higher in Dragon followed by Badsha and lowest in the variety Sonya. Plant growth and yield potentials were found slightly higher in 2018 than that at 2019. Therefore, it can be stated that cultivation of watermelon with Dragon and Badsha varieties is more profitable as compared to Sonya and Black Dorin.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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